Matching parcellations using Optimal Transport: a proof of concept

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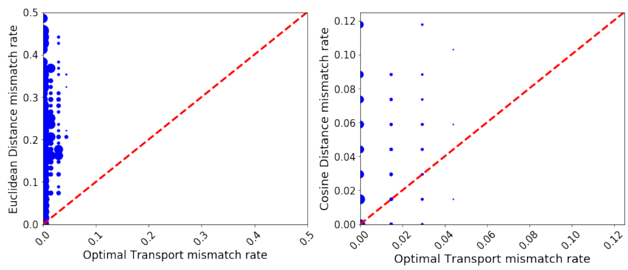
Introduction

Many techniques have been proposed to divide the brain based on structural connectivity [1]. However, even when produced by the same technique, the resulting parcellations tend to differ in the number, shape, and spatial localization of parcels across subject. Matching parcels across subjects is an open problem. We propose to use Optimal Transport (OT) theory to tackle this issue. OT theory studies the efficient transportation of mass between two probability distributions with respect to a certain cost function [2]. As a proof of concept, we show that OT can match parcels of the Desikan atlas [3] across different subjects, using only the structural connectivity fingerprint of each parcel. We use the Desikan atlas since it is used as a prior parcellation in several connectivity studies.

Methods

We randomly selected 20 subjects from the HCP500 dataset of the Human Connectome Project. Every subject is already preprocessed with the HCP minimum pipeline and possesses a coregistered cortical mesh of approximately 32,000 vertices per hemisphere. For each subject, we compute a cortico-cortical extrinsic connectivity matrix using probabilistic tractography from the vertices of the subject's cortical mesh. Each row in the matrix represents the probability of a connection existing between one vertex and the rest of the surface's vertices. Then, we obtain the connectivity fingerprint of every parcel in the Desikan atlas [3] by averaging its vertex connectivity vectors using the technique proposed by Gallardo et al.[4]. For every pair of subjects, using one as origin and the other one as target, we produce an OT-based joint probability matrix as in Gayraud et al.[2], using each parcel's extrinsic connectivity fingerprint as its feature vector. The rows of this matrix indicate the amount of probability mass of a feature vector in the origin space which is transported onto each feature vector in the target space. We produce a parcel matching by matching each origin parcel to the target parcel with the highest joint probability. For comparison purposes we also produce the parcel matchings for each pair of subjects with two additional methods. In the first, we compute the Euclidean pairwise distance matrix across feature vectors, and match each origin parcel to the closest target parcel. Then, we repeat the same process, but using the cosine distance, which is frequently used to compare connectivity fingerprints. To quantify the result of each technique, we count how many parcels are wrongly matched for each pair of subjects, and compute the ratio of mismatched parcels to the total number of origin parcels.

Results



The figure compares the mismatch ratios obtained by the technique based on OT against those based on the Euclidean (left) and cosine distance (right). Each point represents a pair (x, y) where x is the mismatch rate of OT and y the one of the Euclidean and cosine based method respectively, for a single pair of subjects. Note that, the point sizes vary according to the frequency of the result. The dotted line denotes the case where both techniques have an equal ratio of mismatched parcels. We can see that the technique based on OT always achieve a smaller number of mismatched parcels than the one based on Euclidean distance. Also, compared to the technique based on the cosine distance, OT is better in 96% of the cases.

Conclusions

In this work, we have shown that using Optimal Transport to match the parcels of an atlas across different subjects using only information about their parcels' extrinsic connectivity is worth to be explored.

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